Bulletin No. 86 June 10, 1924.

COMMONWEALTH OF PENNSYLVANIA

DEPARTMENT OF FORESTS AND WATERS
R. Y. Stuart, Secretary

TOPOGRAPHIC AND GEOLOGIC SURVEY

G. H. Ashley, State Geologist.

THE AGE AND ORIGIN OF THE EARTH.*

By

George H. Ashley.

The changing earth.

"The eternal hills" is a poetic phrase that expresses the common belief in the stability of the face of the earth. Our Pennsylvania mountains are looked upon as permanent; one feels that they always have been and always will be just where they are; that our rivers, the Delaware, Susquehanna, Allegheny, and others, have always flowed where they are today, and that the Atlantic Ocean has always been where it is now. Most people believe that the earth is dead and practically changeless. But are these things true?

The muddy water of every flood is evidence that each year every stream carries large quantities of sand and silt to the sea. This material has been washed off from the land. A moment's thought must lead to the conclusion that if this process goes on long enough, the valleys become broader and deeper, the hills become more rounded and lower, and the sea fills up. In the end the land will be reduced to a low plain. It is difficult to realize that this process has been completed not once but many times. The flat tops of most mountains in Pennsylvania are remnants of a plain. Before that plain was formed Pennsylvania was a land of vast mountain ranges, perhaps as high and rugged as any in the world today.

Is it possible to form an idea as to how long it might take to reduce the surface of the earth to a flat plain? The best method

---

* An address given before the Harrisburg Natural History Society with lantern slides, March 25, 1924. The writer acknowledges his indebtedness to Mr. M. W. Jacobs, of Harrisburg, for data and criticism of the part relating to the origin of the earth.

Digitized by the Internet Archive
in 2016 with funding from
This project is made possible by a grant from the Institute of Museum and Library Services as administered by the Pennsylvania Department of Education through the Office of Commonwealth Libraries

https://archive.org/details/ageoriginofearth00ashl

of forming such an idea is to examine valleys which have been cut or clay banks laid down since the last retreat of the great ice sheet. The Ice Age was one of the latest incidents in the history of the earth. Imagine a vast sheet of ice forming in northern Canada, growing thicker and thicker year after year, and spreading southward like a body of white tar until it overran northern Pennsylvania. When the ice sheet melted and its margin retreated, ponds formed along its front. In these ponds mud was laid down in very thin layers. The layers that were deposited in winter can be distinguished from those formed in summer; and by counting the layers the number of years it took to deposit them can be estimated just as the age of a tree is estimated by counting the annual rings. Such a count in Sweden indicates from 7,000 to 12,000 years, for the ice retreated slowly.

Measuring geologic time by erosion.

The time that has elapsed since the continental glacier retreated can be measured at Niagara Falls. Niagara Falls is a new falls. It did not exist before the last retreat of the ice. The location and shape of the brink of Horseshoe Falls have been recorded at intervals since 1842. These records show that the falls are retreating about 4 feet a year. The gorge is about 7 miles long. At that rate it would have taken from 7,000 to 9,000 years to cut the gorge as it is now. Similar measurements have been made of other waterfalls with similar results. The Colorado Canyon is another sample of recent erosion. It has been cut since the ice first came, for glacial gravels washed out of the San Juan Mountains are found on the opposite side of the canyon.

A world-wide study of erosion is being made. The quantity of sediments being carried out to sea by great rivers can be measured and an estimate made as to how fast their drainage basins are being lowered. Observations of various rivers throughout the world show that those actually measured carry from 1/71,000 to 1/48 of their weight in suspended sediment. The Mississippi is estimated to carry 566,770,000 tons of mineral matter to the sea in a year. This is equal to 1/3840 of a foot taken off the whole drainage basin each year. The western plains are dotted with buttes, sole remnants of rock strata that once covered the plains to a depth of hundreds of feet. These buttes are a measure of denudation in the Mississippi Valley. The Uinta Mountain region of Utah has lost rocks several miles thick, and 32,000 feet have been carried away from the Wasatch Mountain region. Cliffs in the Colorado plateau reveal the fact that rock strata 6,500 to 11,000 feet thick that were continuous above the top of the present canyon have been removed. The measurement cannot be made in one place but it has been determined that rocks five miles thick have been removed from parts of Pennsylvania.

Coasts rise and sink.

The earth's surface has been changed by agencies other than cutting by water and deposition of sediments in the sea. The pillars

of a temple in Italy are scarred to a height of 12 feet by the borings of marine animals. This temple was built originally on the shore. The coast sank until the building stood in the sea. Later the shore was raised and the temple was again on dry land. Sandy beaches 70 to 700 feet above the present sea level along the coast of California are full of modern sea shells. The presence of these shells is evidence that the coast has been raised. At other places the coast has sunk. The Golden Gate is the mouth of a sunken river. Chesapeake Bay is a sunken valley. The surrounding land was once se bottom, for the sands carry abundant shells, shark teeth, and other remains of marine life. That region therefore must have been raised above sea level and sunk again, but not to its original level.

Wherever the land and the sea meet there are signs of a land movement up or down, generally so slow that there is little historic evidence of the movement. There is no reason for thinking that movement in the past was faster than that of today. At least eighteen times this continent has sunk so that the sea covered each time from one-eighth to one-half of the continent. Each submergence was long enough for thousands of feet of rocks to be laid down. There is no reason for thinking that the continent of America may not again be deeply submerged and buried beneath new deposits of rock material.

Evidence is available that every part of Pennsylvania has been deep under the sea time after time; and that the eastern half of the State was the site of vast mountain ranges. There is a possibility that Pennsylvania will again be at the bottom of the sea, or buried beneath miles of new sediments.

Computing the age of the earth.

One line of evidence used in estimating the age of the earth is found in the rocks that form its surface. Four-fifths of these rocks were formed by deposition of sediments in large bodies of water and are stratified. Where they are now raised above water level and their edges exposed by erosion, the thickness of the beds can be measured. The edges of rocks one mile thick are exposed in the canyon of Colorado River. In Pennsylvania a hole was drilled at McDonald in Allegheny County through nearly a mile and a half of sedimentary rocks. The upturned edges of rocks about five miles thick outcrop from Gallitzin to Altoona and down the Juniata Valley. How long did it take for the streams of former continents to deposit these great thicknesses of sediments in ancient seas? If we use as a measure the quantity of sediment carried out of Mississippi Valley annually, the Mississippi River is lowering its valley at the rate of one foot in 4,000 years. A careful estimate places the average thickness of the bedded rocks in Pennsylvania at 25,000 feet. If they were laid down at the rate of one foot in 4,000 years, their deposition required 100 million years. But the bedded rocks in this State were laid down during only a part of past geologic time. Had sediments been deposited during the whole time, doubtless they would have averaged not less than 50,000 feet in thickness, and would have required more than 200 million years to accumulate. One finds by studying the rocks of Pennsylvania that there were many gaps in

deposition, when the State was more or less above sea level and no sediments were being laid down, or those previously deposited were being eroded. If only the greatest thickness of each of the systems of rocks were added together the total would be 300,000 feet. At the rate of one foot in 4,000 years their deposition would have taken 1,200,000,000 years.

Time required to deposit a foot of coal.

These figures illustrate one type of evidence. As a matter of fact, the subject is not studied in that crude manner but very detailed investigations are made of the rate at which different rocks are laid down. A good illustration of such a study is that of the time required to lay down a bed of coal. Coal consists of plant remains. This is proved by the high-power microscope which shows spores, woody tissue, and other plant fragments in the coal. A study of plants now living shows that the most rapid yearly growth yields about five tons of carbon to the acre. An acre of anthracite one foot thick contains about 1,900 tons of carbon. At the rate of five tons a year, 380 years would be required to deposit one foot of anthracite, making no allowance for loss of carbon through decomposition. The total thickness of all coal beds in the Appalachian coal field is approximately 300 feet. Therefore it would take approximately 100,000 years to deposit this quantity of coal. The rate of 380 years for one foot of coal is the fastest accumulation possible if conditions were as they are today. There is no direct evidence that they were different. The time that elapsed when this coal was accumulating may have been many times longer. Only 300 feet of coal out of 10,000 feet of rock forming the coal measures has been considered. If the other rocks were laid down in proportional lengths of time, the deposition of the coal measure rocks alone would require one billion years.

Pennsylvania once a plain.

The age of the earth may be computed by the time required to erode rocks. Very careful studies have been made of the rate at which different rocks are eroded under different conditions. The rate of erosion in the gorge of Niagara River has been mentioned. The rocks in central Pennsylvania are all standing at steep angles and some are on end. If the rocks that have been worn away were replaced the total thickness would be approximately 40,000 feet. How long would it take to file 40,000 feet of rock down to a plain like Kansas and Nebraska? That filing down of mountains to a plain took place in Pennsylvania in only a small part of geologic time. The remnants of that plain are in the flat tops of the Pennsylvania mountains. These mountains exist, not because they were pushed up, but because the whole State was lifted and the softer rocks were afterward carved out and carried away. This uplift was not sudden or continuous. Many times the movement stopped so long that new plains were begun. All the uplands of western Pennsylvania belong to one of these later periods of stability.

Great lapses of time indicated by changes in animal forms.

Another method of measuring geologic time and the age of the earth is through the changes in the form of animal and vegetal life. One of the latest geologic ages, the Tertiary, is known as the age of mammals. This age is divided into a number of periods which have been distinguished from one another by the percentage of animal species represented by fossils whose descendents are living in the present age. The oldest period contains only a few forms that are living today. About one-half of the forms in the rocks of the middle Tertiary are living now. During the Tertiary age families of animals underwent very remarkable changes. How long did it take for the little four-toed horse of early Tertiary time to become the big, single-toed horse of today, considering how slowly animal forms change now? How long did it take the first little elephant with only rudimentary tusks to change little by little to the huge elephant of today? Changes as great as those in the Tertiary have recurred time and again in geologic history.

The stories of the development of life are read in the fossils. When the thousands of feet of the oldest rocks, including all those under southeastern Pennsylvania, were being deposited, only the very lowest forms of life, the invertebrates, were on the earth. In the next younger strata the skeletons of fish are found with the invertebrates. Above those rocks are thousands of feet of strata which contain, besides the invertebrates and fish, the remains of amphibians, relatives of the frog. Still younger rocks, thousands of feet of which were laid down in the western part of the United States, record the development of reptiles, both great and small. Then came birds and finally mammals, and in the last geologic minute, man.

In these different methods of estimating the age of the earth the assumption has been that conditions in the past were like those of today. The climate was distributed somewhat differently at various periods, but in general there is no direct evidence of any material change in climate.

The age of the earth has been estimated from the saltiness of the sea, and in other ways, with widely differing results. Now a new method of computation has been found.

New method of computing age of the earth.

Not many years ago it was discovered that uranium gives off so-called Becquerel rays, which consist of atoms of helium, negative electrons, and "gamma rays." As uranium gives off these rays the radium content in time disintegrates into a descending series of secondary substances. Ultimately it breaks down into a substance which is practically identical with lead. The time required for this breaking down has been calculated. The rate at which helium is generated is fairly well known, and a method of determining the age of minerals has been based upon that constant. If one knows the

quantity of uranium or radium in a rock or mineral, and also the quantity of radium-lead which it contains in the same volume of material, it is easy to calculate the length of time required to generate the lead, and so the age of the rock. Such determinations involve many assumptions but are consistent within themselves and are in general agreement with the ideas of modern geologists. Studies of uranium in rocks of Carboniferous or earlier age in Connecticut gave 300 million years for their age, which coincides with estimates based on other lines of evidence.

Life 600 million years ago.

All the different methods of computing the age of the earth supplement each other. According to these computations the rocks containing the earliest forms of life were laid down about 600 million years ago. The rocks under the Cumberland-Lebanon-Lehigh Valley in eastern Pennsylvania were laid down about 400 million years ago. The youngest of the coal measure rocks in western Pennsylvania are 200 million years old. These 600 million years represent only the time during which were laid down these rocks containing fossils. Prior to that there was a time, probably equally long, during which life was beginning, but of that life few individual fossils remain; only great beds of limestone and iron ore tell of the life that was. Still earlier was the age when the earth was forming. Estimates of the age of the earth therefore range from one to ten billion years. New facts eventually may multiply or divide these figures.

Origin of the earth.

The origin of the earth is the next problem. To answer it one must take account of all that is known regarding the earth, the sun, the planets, and all the other stars. The size of the earth, its weight, density, and many other facts about it are known. Any theory of the origin of the earth must take account of and explain each of these facts. The naked eye can see about 5,000 stars; with the best telescope about 100 million stars can be seen. Probably there are not less than 1,500 million stars, big and little. Some of them are the thinnest gases, some are as solid as iron.

The earth and the other planets revolve about our sun in almost exactly the same plane and in the same direction, but their axes of rotation are not at right angles to the plane of their revolution nor is that of the sun. The sun has a corona which at certain periods throws out eminations 300,000 miles above its surface. Like the sun, large stars tend to lose mass by radiation. The stars are about one million times as far away as the nearest planets. Sirius is only about 50 million million miles away. The greatest measured distance to a star is 125,000 times greater. Although the stars differ greatly in size, they do not differ much in mass from the sun. Nearly one-half of the stars are double, two stars revolving about each other. Star clusters are made up of many stars all moving with the same general motion, indicating common origin. The great nebulae are less understood but their interpretation may aid in solvin

the puzzle of the origin of the earth.

Spinning, shrinking nebulae.

This is not the place to discuss the various theories that have been offered, and the arguments pro and con. The latest and best theory, the one that most nearly meets all the known facts and conditions, has developed from the minds of many men, including Kant, Laplace, Sir G. Darwin, T. C. Chamberlain, F. R. Moulton, Harold Jeffreys, J. H. Jeans, G. E. Hale, and A. S. Eddington. The basis is a nebulous gas ("fire-mist") thinner than the most perfect artificial vacuum. An electric light bulb is supposed to be a nearly perfect vacuum. If the gas remaining in a bulb were spread through a cubic mile of space some idea of the extreme thinness of one of the nebulae could be gained. A nebula fills a space so vast that it cannot be readily conceived by the human mind. The nebula is assumed to have an initial movement of rotation. It radiates energy and shrinks steadily. According to the laws of mechanics, as a nebula shrinks its speed of rotation increases. As the speed increases, the shape of the mass changes, the diameter through the axis of rotation becomes less, and the equatorial diameter becomes greater. Finally the equator bulges out until it becomes the thin edge of a lens-shaped mass. It does not take much of a pull from a neighboring nebula to upset the balance on that thin edge and start a stream of gas flying off toward the attracting body. Thus a spiral-armed nebula may originate.

In these arms of streaming gas are denser spots. The sun is thought to have had its beginning as one of these spots. Such a spot would tend to condense and shrink, and give off energy. It has been estimated that the temperature of the shrinking body increases to millions of degrees in the center and to 25,000° C. at the surface. A critical point is reached as the body approaches liquification, though it is only 1/10 as heavy as water. Beyond that point the body continues to shrink, but the laws relating to a gaseous body no longer control and the body begins to cool.

Planets condensed gas lured astray.

This dense spot or body in the spiral nebula has no planets; it is not yet the center of a planetary system. The planets could not have been thrown off from the region of its equator for while they lie practically in a plane it is not the plane of the sun's equator. Apparently the planets are the result of an unusual event. Planets are explained by the supposition that some other star, probably much larger, came near to the sun. As it approached it raised a tide on the sun; as it came still nearer it lifted this tide of hot gas or gaseous liquid until some broke away. The stream of gas increased in size until the larger star began to draw away from the sun. As the distance increased the stream of gas diminished and finally stopped flowing. The gas detached from the sun followed after the retreating star, but was left behind, a free separate body. This stream of gas, possibly liquid at the ends, long drawn out, began to condense. At

the ends of the stream cooling was rapid and small planets were evolved. Cooling was slower in the center of the stream where the volume was greater, and the density less and larger planets were formed by the condensing gas. These larger planets, like Jupiter and Saturn, subsequently lost portions of their mass which continued to revolve about the parent as moons.

The earth is between these two extremes. It was not solid enough to maintain its integrity, for the mass of the moon was pulled out from it; but it was so viscous that the moon, the only detached body, is relatively large. The mass of the moon is 1/81 that of the earth, while Jupiter's largest moon is 1/11,000 of the mass of its parent.

The long dark ages of the earth's history are beyond this point. This body of liquid or gas continued to whirl through space, steadily shrinking and losing heat, probably picking up vast quantities of meteoric stones and irons, until, perhaps a billion years ago, its surface became cool and its atmosphere condusive to life.

The earth's history through the geologic ages is another story.